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26 April 1979

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TRANSLATIONS ON USSR RESOURCES
(FOUO 9/79)

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ELECTRIC POWER AND POWER EQUIPMENT

UDC 690.9

POWER STATIONS: RESULTS AND GOALS DISCUSSED

Moscow TEPLOENERGETIKA in Russian No 1, Jan 79 pp 2-4

[Article by Ye. I. Borisov, First Deputy Minister of Power and Electrification of the USSR: "Results of Electric Power Plant Operation in 1978 and Goals for 1979"]

[Text] The year 1978 was a year of further implementation of the complex plan of economic and social development in the life of the Soviet people. Political events of great importance took place in the country: the sixtieth anniversary of the Soviet Regime, acceptance of the new Constitution of the USSR, the December (1977), July, and November (1978) Plenums of the CPSU Central Committee. All this enlivened the activity of the entire Soviet people.

Supporting and approving unanimously the domestic and foreign policy of the Lenin's party, and the theses and conclusions of the program speeches of the Secretary-General of the CPSU Central Committee, Chairman of the Presidium of the USSR Supreme Soviet, Comrade L. I. Brezhnev, power industry workers, just as all Soviet people, are making their contributions to the cause of the strengthening of the economic power of our country.

Fulfilling the tasks of the national economic plan, power industry workers of the country are providing a dependable and economical power supply to the national economy.

In 1978, a considerable increase in the energy potential was achieved. Electric power stations of the Soviet Union produced about 1200 billion kWh of electric energy, including almost 1112 billion kWh at the power plants of the USSR Minenergo [Ministry of Power and Electrification]. Thermal electric power stations produced 82% of electric energy. Heat and electric power stations of the USSR Minenergo delivered 759 million Gcal of thermal energy.

Last year, new power-generating equipment for a capacity of about 10 million kW was put into operation at the electric power stations of the country, including 2-2.5 million kW at AES and 2-2.5 million kW at GES, which is of great importance for improving the fuel and energy balance of the country.

The increase of energy capacities at TES was achieved chiefly through the introduction of large more economical condensation power units with a unit capacity of 200-500 MW and heating units for live steam pressure of 13 and 24 MPa.

The following units were put into operation: a 500 MW power unit at Reftinskaya GRES; 300 MW power units at Iriklinskaya, Stavropol'skaya, and Syrdar'inskaya GRES; 210 MW units at Gusinoozerskaya, Pechorskaya, Smolenskaya, Surgutskaya, Cherepovetskaya, and Shaturskaya GRES; heating units with a capacity of 135-110 MW at Volgograd TETs-3, Lipetskaya TETs, Nizhne-Kamskaya TETs-2, Ivanovskaya TETs-3, Karagandinskaya TETs-3, and Minskaya TETs-4.

At the present time, power production is based chiefly on units operating at a live steam pressure of 24 and 13 MPa which were responsible for more than 79% of electric energy produced by all thermal electric power stations.

Further development of nuclear power engineering was achieved by introducing powerful nuclear energy generating units with a capacity of 1000 MW at the Novovoronezhskaya, Kurskaya, and Chernobyl'skaya AES.

The equipment of the first power units of 1000 MW at the Kurskaya and Chernobyl'skaya AES introduced in 1976-1977 is being used successfully.

Hydropower engineering also developed further last year. The sixteenth hydraulic unit with a capacity of 240 MW was put into operation at the Ust'-Ilimskaya GES. With its introduction, this GES reached the capacity of 3840 MW. At the Sayano-Shushenskaya GES, its first and country's largest hydraulic unit of 640 MW was put into operation.

The introduction of the first three units of 260 MW each was ensured at the Inguri GES. Two units were put into operation at each of the following GES: 300 MW each at the Nurekskaya GES, 215 MW each at the Zeyskaya GES, 78 MW each at the Nizhne-Kamskaya GES.

Further development of the Unified Power System (YeES) was an important area of work. It covers a huge territory which includes the power systems of the Center, South, and Northwest of the country, Transcaucasia, Northern Caucasus, Ural, and Northern Kazakhstan. In 1978, the Integrated Power System of Siberia was connected to the YeES. At the present time, electric power networks cover almost the entire populated area of the country and have a length of over 4.3 million kilometers. Last year, the following high-voltage electric power transmission lines started operating: West Ukraine -- State Boundary 750 kV Line; Stavropol' GRES -- Tikhoretsk, Inguri GES -- Tbilisi, Reftinskaya GRES -- Kozyrevo, Sayanskaya -- Abakan, Toktogul'skaya GES -- Frunze, and Omsk -- Petropavlovsk 500 kV lines; Kakhovskaya -- Dzhankoy 330 kV lines; Shatura -- Noginsk and many other lines of 220 kV.

Much work is being done on improving the dependability, stability, and effectiveness of power systems determining uninterrupted electric power supply to the national economy.

Distribution power transmission lines of 0.4-20 kV about 130,000 km long were introduced for supplying power to rural areas; 27,000 km were built in the nonchernozem zone of the RSFSR alone. Power industry enterprises gave considerable help to kolkhozes and sovkhozes under their partonage in electromechanization of production processes and in training the personnel for these networks.

In 1978, work was continued on the development of the Ekibastuz and Kansk-Achinsk fuel and energy complex. The Ekibastuz complex will include five powerful electric stations with a total capacity of 20 million kW and coal mining enterprises with a total capacity of 120-140 million tons per year.

Construction and installation work is in progress at the Ekibastuz GRES-1 on the first two power units of 500 MW each. It is planned to put them into operation in 1979. The Kansk-Achinsk complex will include electric power stations of a unit capacity of 6.4 million kW, with power units of 800 MW, with a total capacity of about 60 million kW, and power engineering enterprises for coal processing.

In 1978, extensive work was carried out at electric power stations for further improvement of the effectiveness of fuel utilization, which contributed to the successful fulfillment of goals for further lowering of specific fuel consumption. Specific fuel consumption for the delivered electric power was lowered in comparison with 1977 by more than 3.0 g/(kWh), and for thermal energy -- by 0.1 kg/Gcal. This made it possible to save about three million tons of specific fuel for the national economy.

The reduction of specific fuel consumption for the delivered electric power was achieved as a result of the improvement of the structure of power production [1 g/(kWh)], operation economy of the equipment of electric power stations [0.6 g/(kWh)], and improvement of the effectiveness of heat supply [1.5 g/(kWh)].

The improvement of the structure of electric power production was ensured as a result of the introduction of highly economical units, removal of worn-out and outdated equipment, and implementation of measures directed toward reducing the use of noneconomical TES units. Thus, the utilization factor of the installed capacity of condensation equipment operating on steam with a pressure of 9 MPa dropped in comparison with 1977 from 62.3 to 59.2 percent.

Increased economy in the operation of electric power stations was also achieved as a result of the reconstruction and modernization of their equipment, improvement of the layout of heating systems, and improvement of the technical level of operation. The implementation of measures for the modernization of the existing equipment was continued; this included the replacement of low-pressure rotors of the turbine sets of 300 and 200 MW power units and turbine diaphragms, and the installation of more effective burners, steam superheaters, and other assemblies on steam boilers.

The production of electric energy in the district heating cycle increased by 0.5% and reached 21.2%. At TETs with equipment for a live steam pressure of 13 MPa, the specific fuel consumption amounted to 254 g/(kWh). The lowest specific fuel consumption -- at a level of 150-170 g/(kWh) -- was at the Nevinnomyssk GRES, Baku TETs-1, Groznenskaya TETs-3, Krasnoyarsk TETs-1, and Sterlitamak TETs when their turbine sets worked in the district-heating cycle.

In order to increase further the effectiveness of district-heating systems, it is necessary to increase the utilization of the thermal power of some TETs by speeding up the construction of heating networks, making new economical turbine sets (T-250, T-175, PT-135, PT-80) fully operational within standardized periods of time, and implementation of a complex of measures for the modernization of individual assemblies and technological flow diagrams of the operating equipment, as well as the reconstruction of condensing turbines with organization of regulated steam bleeding and switching them to the operation mode with counterpressure and a worse vacuum.

For the group of 800 MW energy units, the specific fuel consumption was lowered by 4 g/(kWh) and constitutes 331 g/(kWh). The specific fuel consumption at the 800 MW energy units of the Zaporozhskaya and Uglegorskaya GRES was 325 g/(kWh). The reliability of the operation of the equipment at these electric power stations has improved considerably.

There was a considerable improvement in the operating economy of the groups of power units of 300 and 200 MW. Their average specific fuel consumption decreased in comparison with 1977 respectively by 1.3 and 0.8 g/(kWh), being 336.3 and 352.9 g/(kWh). The lowest specific fuel consumption of 318-320 g/(kWh) at electric power stations with 300 MW power units operating on gas and oil fuel was achieved at the Iriklinskaya, Karmanovskaya, Kostromskaya, and Sredne-Ural'skaya GRES. Among coal-operated electric power stations, the best specific fuel consumption of 333-336 g/(kWh) was achieved by the Belovskaya, Yermakovskaya, and Reftinskaya GRES.

However, not all electric power stations used the available reserves for increasing the effectiveness of fuel utilization, and the consumption of fuel at some stations exceeded the established norms. Such electric power stations include: Slavyanskaya, Nazarovskaya, Pridneprovskaya, Navoiyskaya GRES, and others.

The main factors affecting the reliability and operating efficiency of power equipment are its maintenance in a proper technical condition and high-quality overhauls.

In 1978, more than 720 boilers with a total capacity of 210,000 t/h and about 570 turbine sets with a capacity of 47 million kW were overhauled. In performing such a volume of overhauling, the most important indexes are the assurance of the quality and deadlines of such jobs, as well as the lowering of the repair cost and labor input. This requires timely and high-quality preparation for overhauling, raising of the level of working out the technology and organization of jobs, and assurance of the necessary quality documentation, materials, and spare parts.

Serious attention should be given to the organization of careful acceptance of equipment after repairs. The quality of performed repairs must be evaluated on the basis of rapid tests and normative operation indexes of the equipment.

It is necessary to give more attention to improving the quality of maintenance of auxiliary equipment which is one of the important factors of efficiency improvement.

An important role in major overhauls is played by the availability of minor mechanization facilities. It is also necessary to improve the development of measures for a better utilization and workload scheduling of the maintenance bases of enterprises.

Work was continued in the power systems on the implementation of a complex of measures for environmental protection.

Last year, the ash-trapping equipment was reconstructed on 73 steam boilers, which made it possible to reduce annual ejection of ash into the atmosphere by 310,000 tons. The pollution of public water reservoirs by waste waters of electric power stations also decreased. An experimental industrial model of a high-temperature electric filter was put into operation on boiler No 6 at the Kostromskaya GRES.

The initiative of socialist competitions to make the year of 1978 a year of outstanding labor and to ensure the achievement of the highest results with the lowest expenditures was taken up by many enterprises and contributed to renewed enthusiasm in the struggle for early fulfillment of the 1978 plan. Much attention was given to shortening the time of attaining rated indexes. The rated specific fuel consumption was attained ahead of schedule at the power units No 8 and 9 of 500 MW each at the Troitskaya GRES and at the power units No 5, 6, and 7 of 800 MW each at the Zaporozhskaya and Uglegorskaya GRES.

The workers of the Belglavenergo [Belorussian Main Power Supply Administration], Troitskaya GRES, and other enterprises initiated stepped-up plans for 1978 for early fulfillment of the tasks of the third year and of the five-year plan as a whole.

Many collectives of the industry supported the initiative of the enterprises of Rostovskaya Oblast "To work without lagging", and the initiative of Zaporozhskaya Oblast "Let machines do manual labor". They introduced a new form of competition -- "Labor relay race", and are developing creative scientific and technical cooperation in utilizing the experience of twenty-eight Leningrad organizations participating in the construction of the Sayano-Shushenskaya GES.

In 1979, power industry workers of the country have to solve large-scale problems in connection with further development of the power industry in the country, organization of power supply to the national economy, improvement of the effectiveness of production and quality of work, and observance of the policy of economy of energy resources in the national economy.

Country-wide electric power output will reach 1265 billion kWh, and the power output of the USSR Minenergo stations will increase to 1176.4 billion kWh. Atomic electric power stations will produce about 42 billion kWh and hydroelectric power stations will produce 172 billion kWh of electric power. The production of thermal energy by power industry enterprises will amount to 855 million Gcal.

It is necessary to reduce the specific fuel consumption used for the delivered electric power to 329 g/(kWh).

Extensive work has to be done in order to increase labor productivity.

Many enterprises are consistently observing the policy of fuel and energy conservation. In this respect, the valuable experience of the workers of the Kostromskaya GRES should be used more widely. As a result of the implementations of measures for the reconstruction of the equipment and maintaining a high technical level of its operation, their specific fuel consumption is less than the rated values.

In 1979, it is planned to introduce new power capacities of 12.5 million kW.

The power industry workers and builders participating in construction of a power unit of 1200 MW at the Kostromskaya GRES promised to complete its installation in 1979.

In accordance with the resolution of the 25th Congress, nuclear electric power engineering will develop rapidly in the European part of the country.

An important place among large electric power stations will be occupied by the Chernobyl'skaya and Kurskaya AES which are now under construction. In 1980, the third power units of 1000 MW each will be completed at these stations. Yuzhno-Ukrainskaya and Smolenskaya AES will start operating.

Much attention is being given by the power industry to the development of a large base in the West-Siberian oil and gas region. Surgutskaya GRES is being expanded. A highly effective complex of very large electric power stations will be created in Tyumenskaya Oblast.

In order to expand intersystem connections, the following electric power transmission lines will be introduced: 750 kV Kurskaya AES -- Bryansk, and Chernobyl'skaya AES -- Rovno; 500 kV Chusovaya -- Severnaya, Magnitogorsk -- Beketovo and others.

In order to fulfill the tasks set for 1979, it is necessary to mobilize the efforts of collectives of associations, organizations, and enterprises of the USSR Minenergo for improving the effectiveness of the utilization of power production and the fuel and energy resources, to maintain the policy of economy, and to spread widely socialist competitions for achieving high work indexes.

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ELECTRIC POWER AND POWER EQUIPMENT

UDC 621.311

INTEGRATED POWER SYSTEMS OF SIBERIA AND THE FAR EAST DESCRIBED

Moscow TEPLOENERGETIKA in Russian No 1, Jan 79 pp 5-8

[Article by A. I. Maksimov, board member of the USSR Ministry of Power and Electrification]

[Text] The development of the power systems of Siberia and the Far East determines to a considerable degree the growth of the entire Soviet power industry and the Unified Power System (YeES) of the Country.

At the present time, the YeES of the USSR includes the Integrated Power System (OES) of Siberia which, in turn, includes the Omsk, Novosibirsk, Barnaul, Tomsk, Kuzbass, Krasnoyarsk, Irkutsk, and Buryat power systems. The Chita power system which is within the zone of the Far East operates in parallel with the OES.

The oil-producing regions of Tyumenskaya Oblast get their power supply from the Surgutskaya GRES which is within the Sverdlovsk power system of the Ural OES.

The Eastern OES has been created. It includes the Amur, Khabarovsk, and Primorye power systems and is operating separately.

The remaining power systems of the Far East (Yakut, Magadan, Kamchatka, Sakhalin) and the Noril'sk power center of Siberia are operating in isolation.

The Integrated Power System of Siberia is one of the largest systems of the country. Its territory exceeds three million km^2 and is more than 2000 km from west to east.

The country's largest hydroelectric power stations are located in Siberia: Krasnoyarskaya (six million kW), Bratskaya (4.5 million kW), and Ust'-Ilimskaya (3.8 million kW). In 1978, the first, country's largest hydraulic unit of 640 MW was put into operation at the Sayano-Shushenskaya GES with a rated capacity of 6.4 million kW. Hydroelectric power stations of the Angara-Yenisey system provide more than 40% of the total output of all USSR GES.

The OES of Siberia has thermal electric power stations with a capacity of over one million kW: Nazarovskaya, Tom'-Usinskaya, Belovskaya GRES, Krasnoyarskaya GRES-2, Irkutskaya TETs-10. The first 210 MW units have been put into operation at the Gusinoozerskaya GRES in Zabaykal'ye with a rated capacity of 2.1 million kW. Electric power and heat for large cities (Omsk, Novosibirsk, Kemerovo, Krasnoyarsk, Irkutsk, and others) are supplied from TETs of 500 MW and more.

The power systems of Siberia are connected by 500 kV networks (Figure 1). The main lines of Siberia are: 500 kV two-circuit transit Irkutsk -- Bratsk -- Krasnoyarsk -- Nazarovo -- Anzhero-Sudzhensk, and 500 kV one-circuit transit Anzhero-Sudzhensk -- Novosibirsk -- Barnaul -- Rubtsovsk.

From the OES of Kazakhstan, power is transmitted through the 500 kV transmission line Yermakovskaya GRES -- Omsk and Yermakovskaya GRES -- Rubtsovsk -- Ust'-Kamenogorsk; the Rubtsovsk -- Ust'-Kamenogorsk section is temporarily working at 220 kV.

Networks of 220 kV connect the Chita power system with the OES of Siberia and an electric power transmission line of 220 kV connects the Gusinoozerskaya GRES (USSR) with Darkhan (MNR [Mongolian People's Republic]) and the power system of the MNR.

A 220 kV line is built along BAM [Bakal-Amur Trunk Line] which will connect regions of Siberia and the Far East. The OES of Siberia differs sharply from other power supply associations with respect to the structure of power capacities and conditions of power consumption. It has the most solid load schedules (the variable part of the day's schedule constitutes only about 13%), and the share of GES in the total installed capacity exceeds 50%. In this connection, in spite of the overall high possibilities of electric energy production at the GES of Siberia, their capacity cannot be used in the solid schedule of loads. The OES of Siberia has considerable excesses of peak capacities (about 3 million kW) which can be used for transmitting power to other regions with more uneven loads.

The main problem of the operation modes of the OES of Siberia in connection with the great importance of the GES situated on various rivers is the optimal utilization of water power resources with the most economical loads of thermal electric power stations. Lake Baikal is a regulating water reservoir for all GES of the Angara system. It accumulates the reserve of water created during the spring-summer period. This reserve is used in winter when the needs of the national economy in electric power increase. The utilization of the water resources of Lake Baikal must be regulated in such a way that only the volume of water which the Angara carries under the conditions of unregulated runoff is used. Only the redistribution of the water resources by the seasons of the year should occur.

The effectiveness of the utilization of the water resources of Siberian rivers characterized by the asynchronous mode is increased considerably due to the operation of all GES in the association. For example, during the flood

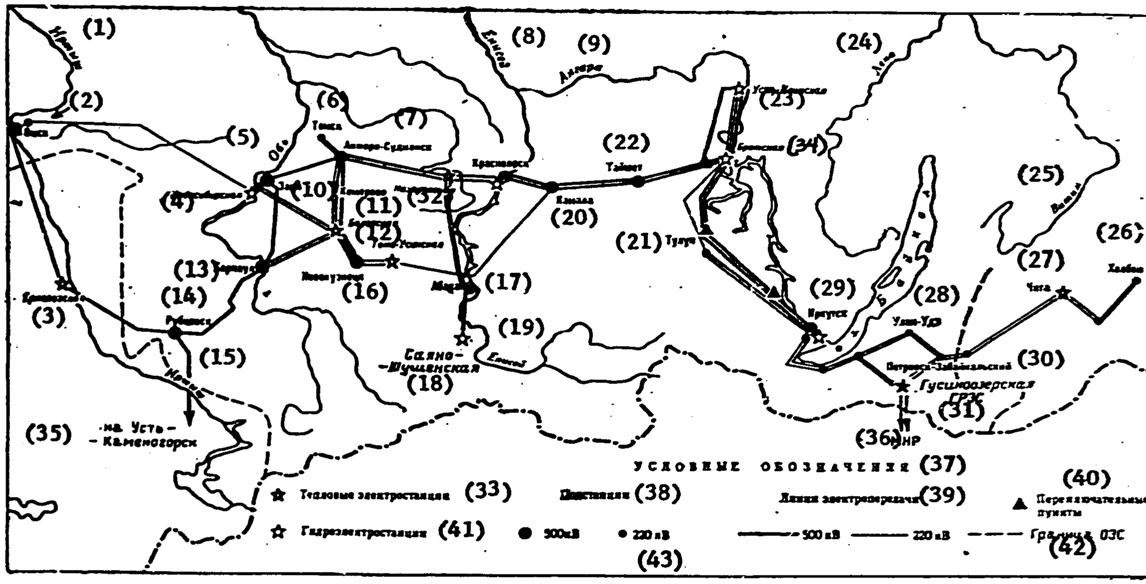

Figure 1. Schematic Map of Main Electric Power Networks of the OES of Siberia for 1978

Key:
1. Irtysh
2. Omsk
3. Yermakovskaya
4. Novosibirskaya
5. Ob'
6. Tomsk
7. Anzhero-Sudzhensk
8. Yenisey
9. Angara
10. Zarya
11. Kemerovo
12. Tom'-Usinskaya
13. Barnaul
14. Rubtsovsk
15. Irtysh
16. Novokuznetsk
17. Abakan
18. Sayano-Shushenskaya
19. Yenisey
20. Kamala
21. Tulun
22. Tayshet
23. Ust'-Ilimskaya
24. Lena
25. Vitim
26. Kholbon
27. Chita
28. Ulan-Ude
29. Irkutsk
30. Petrovsk-Zabaykal'skiy
31. Gusinoozerskaya GRES
32. Nazarovskaya
33. Thermal electric power stations
34. Bratskaya
35. to Ust'-Kamenogorsk
36. MNP [Mongolian People's Republic]
37. Conventional Symbols
38. Substations
39. Electric power transmission lines
40. Switching points
41. Hydroelectric power stations
42. OES boundary
43. kV

period on the Yenisey, the Krasnoyarskaya GES produces excessive amounts of electric power. As a result of this, the presence of electric connections makes it possible to reduce the flow of power to the Krasnoyarsk energy system from the Irkutsk energy system where during this period the output of the Bratsk GES lowers and a part of the Angara runoff accumulates in the water reservoir. During the period when the Yenisey water level is low, the output of the Bratskaya GES increases and, accordingly, the flow of electric power increases from the Irkutsk energy system to the Krasnoyarsk system.

Hydroelectric power stations on the Angara are used also for regulation over many years. For example, the output of electric power of the Bratskaya GES in 1974 amounted to 28 billion kWh, which was 24% higher than the averave for many years, and in 1977 it was 19.7 billion kWh, which was 7% less than the average for many years.

During the years when the level of water is low, the production of electric power at the GES of Siberia can drop by 10-11 billion kWh in comparison with the level for many years, which makes the balance of electric power of the association considerably heavier and leads to the necessity of maximum loading of thermal electric power stations and increased transfers of electric power to Siberia.

The operation modes of the main network of the association are determined by the distribution of the largest hydraulic and thermal electric power stations in Eastern Sibera -- in the Irkutsk and Krasnoyarsk energy systems which have considerable excesses of power, which causes considerable transfers to deficient power systems of Western Siberia.

The operating mode of the main Siberian network is characterized by complete utilization of its carrying capacity almost in all sections. The most heavily loaded 500 kV transit lines are Bratsk -- Irkutsk and Krasnoyarsk -- Anzhero-Sudzhensk which connects the power systems of Western Siberia (Kuzbass, Tomsk, Barnaul, and Novosibirsk) with the rest of the OES.

The 500 kV electric power transmission line Yermakovskaya GRES -- Omsk transmits power from Kazakhstan to the Omsk power system which does not produce enough power.

The Integrated Power System of Siberia was switched to operate in parallel with the YeES of the USSR in September 1978 when a 500 kV Novosibirsk -- Barnaul electric power transmission line was introduced and, thus, the work was completed on the construction of a 500 kV intersystem transit line Ural -- Kazakhstan -- Siberia of about 2200 km. The connection of the OES of Siberia was a decisive step toward the completion of the formation of the Unified Power System of the country. The area covered by the YeES increased to 10 million km square, and the production of electric energy at its electric power stations reached almost 90% of the total union output.

The connection of the OES of Siberia to the YeES of the USSR increased the effectiveness of the utilization of Siberian GES, improved the level of economy of the operation of thermal electric power stations of Kazakhstan and Ural, and increased sharply the reliability of power supply to the regions of Western Siberia and Kazakhstan.

Due to a four hour difference in the zone time in comparison with the Moscow time, the load of the OES of Siberia during the maximum load at YeES lowers by nearly two million kW.

The transmission of power between Siberia and the remaining part of the YeES is determined by the stability of the 500 kV transit line and amounts to 500 MW in both directions.

During the hours of daily maximum loads at YeES, the streams of power are directed from the OES of Siberia to the YeES, which makes it possible to use the excessive peak power of the Siberian GES in the low-level power supply regions of Kazakhstan and the Urals, during slack hours, the power produced at thermal electric power stations of Kazakhstan and the Urals is transmitted to Siberia, which makes it easier to maintain the balance of electric energy of the association. Due to the reversive nature of power transfers between Siberia and the YeES, the obtained effect exceeds one million kW.

The connection through the 500 kV electric power transmission line of Siberia with the YeES is inadequate. Its carrying capacity constitutes approximately 2% of the power of the OES of Siberia, therefore it cannot ensure the necessary transfers of power connected with the realization of all advantages of parallel operation. For parallel operation of the OES of Siberia with the YeES, one of the most important problems is to ensure reliable and stable operation of the intersystem connections. This is ensured by systems for controlling power transfers in normal conditions and automatic emergency systems for preventing or correcting emergency situations.

In normal conditions, the connections of the Siberia -- Kazakhstan -- Ural lines are regulated by the dispatchers of integrated dispatching controls (ODU) of Siberia and Kazakhstan. The dispatcher of the ODU of Kazakhstan regulates power transfers of Kazakhstan -- Ural and, if he has some difficulties, he requests the dispatcher of the ODU of Siberia to help him in this.

The dispatcher of the ODU of Siberia regulates power transfers for the Siberia-Kazakhstan line and helps in regulating the transfers for the Kazakhstan-Ural, if the load of the Siberian -- Kazakhstan transmission line makes it possible for him. The automatic system for regulating power transfers operates on the same principle.

The automated system of the Siberia - Kazakhstan -Ural line ensures the invariance of the working conditions in various parts of the power supply association as a result of the balancing action of the automatic equipment. When 500 kV lines are switched off or when too much power is sent to them, the generators of the Yermakovskaya, Troitskaya, Iriklinskaya GRES, and others are disconnected (or unloaded), parts of the loads in low-level power centers

(Barnaul'skiy, Rubtsovskiy, Tselinogradskiy, and others) are switched off, and control commands are transmitted at hundreds of kilometers. For serious accidents when the balancing automatic equipment cannot ensure synchronous operation, provision is made for separating automation, automation of frequency unloading, frequency starting of standby units, and automatic frequency connection of disconnected consumers.

One of the USSR's first complexes of automatic emergency equipment with the use of controlling computers is being created for the Ust'-Ilim-Bratsk center. Emergency control systems are being developed with the use of electronic computers for the Krasnoyarskaya and Sayano-Shushenskaya GES.

By combining the high operational discipline with automatic control of power transfers and emergency automatic equipment makes it possible to ensure stable parallel operation of the OES of Siberia with the Unified Power System.

Long-range development of the unique deposits of the Kansk-Achinsk brown coal fields with the construction of the GRES of the Kansk-Achinsk Fuel and Energy Complex (KATEK) of 6.4 million kW each, and each with a total capacity of several tens of millions of kilowatts, and the introduction of the full capacities of 6.4 million kW of the Sayano-Shushenskaya GES, Boguchanskaya GES of 4 million kW, and other largest GES of Siberia will increase the role of the OES of Siberia in the power engineering industry of the country and its effect on the operating conditions of the Unified Power System as a whole.

Due to the utilization of the Kansk-Achinsk coal, more than 25% of the total needs of electric power stations of the OES of Siberia in fuel is satisfied even now. In the next 10-12 years, the annual need in this coal will increase 3-4-fold, and the first GRES of KATEK alone will be burning more coal than all electric power plants of the OES of Siberia are burning today. Kansk-Achinsk coals will be used also in other regions of the country.

Optimal utilization of the KATEK GRES and complete utilization of the GES of Siberia in covering the load schedules of YeES can be ensured by constructing a powerful Siberia -- Kazakhstan -- Ural 1150 kV alternating current line with a carrying capacity of 5-6 million kW. This main transmission line passing through the main centers of Western Siberia, Kazakhstan, Southern Ural, will ensure large scale maneuvering of power fluxes, transmitting 4-5 million kW during the maximum load of the YeES from Siberia to Kazakhstan and to the Urals, and transmitting back up to 3-4 million kW during the slack hours.

The first section of this main line, Itat -- Kuzbass, is being constructed during this five-year plan. In the middle of the Eleventh Five-Year Plan, section Ekibastuz -- Ural must be put into operation for delivering power from the Ekibastuz GRES, and in the beginning of the Twelfth Five-Year Plan, the construction of the entire 1150 kV transit line Siberia -- Kazakhstan -- Ural must be completed.

It is planned to construct several very large Surgut GRES operating on incidental gas with capacities of 4.8-7.2 million kW. This will require the

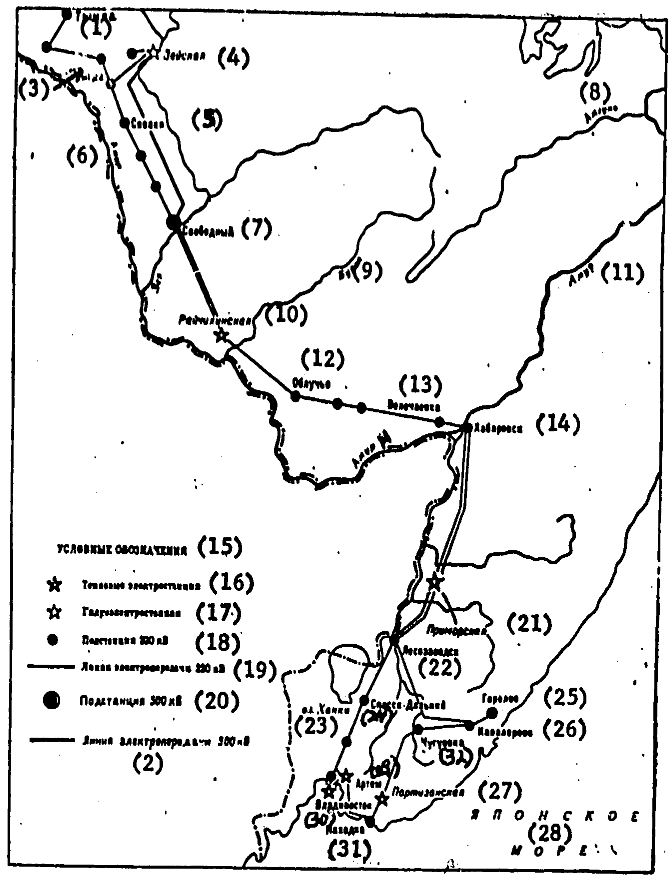

Figure 2. Schematic Map of Main Electric Power Networks of the OES of the East for 1978

Key:
1. Tynda
2. Electric power transmission line, 500 kV
3. Tygda
4. Zeyskaya
5. Sivaki
6. Amur
7. Svobodnyy
8. Amgun'
9. Bureya
10. Raychikhinskaya
11. Amur
12. Obluch'ye
13. Volochayevka
14. Khabarovsk
15. Conventional signs
16. Thermal electric power plants
17. Hydroelectric power plants
18. Substations, 220 kV
19. Electric power transmission lines, 220 kV
20. Substations, 500 kV
21. Primorskaya
22. Lesozavodsk
23. Khanka Lake
24. Spassk-Dal'niy
25. Goreloye
26. Kavalerovo
27. Partizanskaya
28. Sea of Japan
29. Artem
30. Vladivostok
31. Nakhodka
32. Chuguyevka

construction of an 1150 kV electric power transmission line Surgut -- Ural. These main lines will become the eastern link of the main 1150 kV network of the Unified Power System.

The Integrated Power System of the East which eventually will cover the entire territory of the southern and central parts of the Far East is now under construction. The territory covered by the OES of the East exceeds 1500 kilometers in length. The largest electric power stations are: Zeyskaya GES, which is under construction, and Primorskaya GRES. Large TETs are operating in the cities of Vladivostok, Khabarovsk, and Komsomol'sk. The power systems of the association are connected by 220 kV networks (Figure 2). Construction is under way on the 500 kV electric power transmission line Zeyskaya GES -- Svobodnyy -- Khabarovsk; its first section, Zeyskaya GES -- Svobodnyy, has been put into operation.

With the completion of the 220 kV Neryungrinskaya GRES -- Tynda electric power transmission line in 1979, Aldanskiy Power Region of the Yakut Power System will be connected to the OES of the East. The operating conditions of the OES of the East are determined by the problem of the most rational utilization of the capacity of the Zeyskaya GES when its water reservoir is filled and reduction of power production at small uneconomical electric power stations, or even their elimination after the appropriate regions are reliably connected to the integrated power system.

Because of the long distances between the centers and the relatively low transmission capacity (100-200 MW) of the intersystem 220 kV connecting lines, the operation modes of the electric networks of the association are intense, which will be considerably alleviated after the introduction of the 500 kV electric power transmission lines Zeyskaya GES -- Khabarovsk and Primorskaya GRES -- Vladivostok.

At the end of this five-year plan when the Komsomol'sk power center is connected through the 220 kV Khabarovsk -- Komsomol'sk electric power transmission line, almost the entire Khabarovsk power system will be included in the association.

Further development of the OES of the Far East depends greatly on the 220 kV electric power transmission lines which are being built for supplying power to BAM [Baykal-Amur Trunk Line], as well as on the large electric power stations which are under construction in its zone: Neryungrinskaya GRES in Southern Yakutiya with a capacity of 0.6 million kW, Bureyskaya GES on the Bureya River with a capacity of 1.7 million kW, Mokskaya GES on the Vitim River with a capacity of 1.5 million kW, and Kharanorskaya GRES with a capacity of 1.3 million kW in the Chita power system.

After the introduction of these electric power stations in the networks which are being built for supplying electric power to BAM, it is planned to connect the OES of the East to the YeES in the Twelfth Five-Year Plan.

With the connection of two power associations of Central Asia which are still operating separately (in the Eleventh Five-Year Plan) and of the East (in the Twelfth Five-Year Plan) to the Unified Power System, the work on its formation will be practically completed.

Only relatively small remote power systems and power centers of the Far East will remain outside the YeES. Their total power output will constitute 1-2% of the union's total.

The integrated power systems of Siberia and the East, which will cover almost one half of the entire territory of the Unified Power System of the country and will yield about 20% of the electric energy produced in it, will have a determining effect on the energy balance and operation modes of the YeES of the USSR.

An important task for the utilization of available reserves and improvement of the effectiveness of the YeES is to include in the energy balance of the European regions of the country 4-5 million kW of excessive peak capacities of Siberia which form as a result of a large share of GES, a solid load schedule, and difference in the zone time. For this, it is necessary to speed up the construction of the 1150 kV electric power transmission line Siberia -- Kazakhstan -- Ural as the main line of the eastern zone of the Unified Power System.

The combination of large GES of Siberia with the GRES of the Ekibastuz and Kansk-Achinsk complexes ensures their maximally effective loading with the use of thermal electric power plants in their basic operation mode and transfers of considerable capacities of the Siberian GES to the variable part of the load schedule. The most important task for ensuring complete utilization of the electric power stations of the OES of the East is the construction of the 500 kV electric power transmission lines Primorskaya GRES -- Vladivostok and Zeyskaya GES -- Khabarovsk to which the Bureyskaya GES will be connected later.

These main transmission lines will create strong connections between the main hydraulic and thermal electric power stations for their optimal utilization for taking care of excessive loads. Their creation will be the necessary condition for the preparation of the OES of the East for operation within the Unified Power System of the country.

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ELECTRIC POWER AND POWER EQUIPMENT

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DEVELOPMENT OF SIBERIAN POWER SYSTEM DISCUSSED

Moscow TEPLOENERGETIKA in Russian No 1, Jan 79 pp 8-12

[Article by A. A. Beschinskiy and A. A. Makarov, Doctors of Economic Sciences, All-Union State Planning Surveying and Scientific Research Institute of Power Systems and Electric Power Networks, and Institute of High Temperatures of the USSR Academy of Sciences]

[Text] The development of productive forces of Siberia is closely connected with the creation of the largest fuel and energy base in this region. This determines the leading role of the fuel and energy complex (TEK) in the formation and structure of the productive forces of the region and the necessity of speeding up their development in comparison with other regions of the country.

The conditions of the development of the fuel and energy complex predetermine preferential placement of industries consuming large amounts of energy in Siberia and stimulate the development of deep fuel processing, and industries producing fuel and energy equipment and using fuel as a raw material (primarily petrochemical enterprises). An important characteristic of the next stage is the appearance of objective economic prerequisites for placing in Siberia such industries which consume relatively moderate amounts of energy for their main line of production but bring about considerable indirect power consumption (for example, for municipal and domestic services).

According to the evaluation of the authors, the realization of such a program would make it possible by the end of the twentieth century to increase the share of Siberia in the total consumption of energy resources by a factor of 1.3-1.4, ensuring the rate of the annual increment of energy consumption by 20-30% higher than the country's average.

This relocation of consumers to inexpensive fuel and energy bases increases the effectiveness of the national economic production. However, it does not eliminate, but only somewhat alleviates the acute problem of fuel supply in the European regions of the country. The essence of this problem is in the fact that, even with accelerated development of nuclear power engineering, the energy resources of the European regions will be able to satisfy only a little more than one half of their needs in fuel and energy (including export) during the period under consideration. The remaining part of energy resources must come in increasingly larger amounts from the eastern regions of the country, and increasingly from Siberia. By the end of this century, Siberia, evidently, will not only perform these functions in relation to the European regions, but will also play an increasingly important role in energy supply of the Far East, Kazakhstan, and Central Asia, compensating them for their delivery of fuel and energy to the European regions through the existing power lines.

It is important to stress that modern economy is extremely sensitive to limitations in energy consumption: according to the authors' calculations, a forced reduction of production (and consumption) of energy resources by 1% reduces the national income by 1.2% and the consumption fund by 0.9%. Under these conditions, it is particularly important to ensure full satisfaction of rational needs of the national economy in fuel and energy even if this requires additional capital investments. In this connection, two special-purpose programs acquire a special national economic significance: development of oil and gas resources in Western Siberia and accelerated development of the Kuznetsk and Kansko-Achinsk coal fields.

The content and forms of realization of these programs require special clarification. It is important to stress that the implementation of these programs will make it possible to obtain more than two thirds of the total increment of the production of energy resources in the country in the last quarter of the twentieth century as a result of using the least expensive fuel, i.e., they are most effective (and not only within the limits of the fuel and energy complex). At the same time, the expenditures on the realization of these programs are measured by many tens of billions of rubles, 25 to 40% of which have to be spent on related branches of the national economy 7-10 years earlier than the main production capital investments.

The creation of large fuel bases and the fuel processing industry, further development of other natural resources of Siberia, and the development of the appropriate processing industries and machine building create important problems in connection with energy and fuel supply to the consumers within the territory of Siberia. The solution of these problems is characterized by the necessity of not only rapid quantitative growth, but also a qualitative improvement of the fuel supply of this region. The latter is explained by the fact that the needs in fuel are satisfied here chiefly with coal, which is often of low quality. In the European regions of the country, the share of high-quality fuel (oil and gas) constituted 65% in 1975, while in Siberia and in the Far East it did not exceed 16%.

This situation is not justified by the fact that local coal is relatively inexpensive. This is true when such coal is used at large electric power stations, but it is improper to use it for small boiler rooms and most technological and domestic units. Here, the use of coal (particularly the ordinary kind) is connected with considerable losses to the national economy, particularly because these consumers account for 40% of the total fuel and

and energy consumption of Siberia. The following main factors are responsible for this situation:

1) overexpenditure of fuel when coal is burned instead of a high-quality fuel (for small consumers, not less than by 10-12%), which, on the region-wide scale, results in annual overexpenditure of funds for the extraction, railroad and highway transportation of tens of millions of tons of coal;

2) unproductive overexpenditure of scarce manpower resources connected with excessive extraction and transportation of coal and ash, as well as operation of power units (about 100,000 people are now engaged in Siberia at small boiler rooms);

3) manpower shortage. Creation of favorable ecological environment is of great importance in the complex of measures directed toward solving the problem of manpower resources for the regions of Siberia. This requires a qualitative improvement in the fuel and energy supply to the cities of Siberia.

The ways of solving these problems must be different from those accepted for the European regions of the country. It would be wrong to attempt to achieve the same high percentage of oil and gas in the fuel and energy balance of Siberia (although it is important to increase it above the existing level) due to the fact that the difference in the socially necessary expenditures on these fuels and coal in Siberia is 2-3 times higher than in the European regions of the country. Under these conditions, it is more appropriate to speed up the electrification of the national economy and to expand the centralization of heat supply chiefly on the basis of district heating systems. Now we shall discuss concrete ways of the realization of the above-mentioned directions in the improvement of the fuel and energy supply to the national economy of Siberia.

The most important index of the quality of power supply is the level of electrification of the national economy. For Siberia, this problem is especially acute, since it has the most important power-consuming industries, coal is the most important fuel, electric power is relatively inexpensive, and, due to limited manpower resources, it is necessary to ensure the most effective application of labor in all spheres, including services and household needs. These leads us to a fundamental conclusion: the level of electrification in all branches of the national economy and the rate of growth of electric power consumption in Siberia must be higher than the USSR average. However, at the present time they are approximately equal with reapect to the country's average.

The placing of new energy-consuming industries in Siberia itself determines increased indexes in the level of electrification of its national economy. It should be stressed, that the development of large energy-consuming industries in Siberia is the most economical way for involving highly economical energy resources in the national economy. The exportation of some of the products produced in Siberia which require a high power input to the European regions of the country will be one of the main ways of the participation of

Siberia in the interrayon labor division of the entire country. The share of the energy-consuming branches of industry in the electric power consumption of Siberia reaches 30%, while the country's average is about 15%. The average union level of the electrification of the national economy (calculated as a percentage of the finite energy obtained from the electric energy in the overall consumption of the finite energy) during the period under examination will increase, probably up to 20%. Consequently, just as a result of increasing the share of electric-power-consuming branches of industry, the level of the electrification of the national economy of Siberia must reach at least 24-25%.

Increased electrification of Siberia is also facilitated by the ratio of expenditures on high-quality (technological) fuels and electric energy. The relatively low cost of electric energy stimulates its use in those technological, agricultural, public, and household processes which it is expedient to orient in other regions of the country toward direct utilization of fuel.

Thus, the examination of the expenditures on the production of some types of products with the use of fuel and electric energy has shown that, in comparison with the European regions, Siberia has obvious advantages for the electrification of such important processes as the production of cast iron, commercial carbon steel, and heating of metal for forging and pressing (mass high-temperature processes of machine building).

In construction and transportation, the level of electrification should be achieved chiefly as a result of the electrification of nonstationery power processes. Along with the electrification of railroads, it is expedient to replace internal combustion engines by electric traction in quarrying (trolly-type dump trucks, electric excavators, etc), in the sphere of city transportation, and, partly, in construction.

The use of electric energy in agriculture will make it possible to increase the productivity of labor considerably. Evidently, it is also expedient to use electric energy partially for supplying heat to agriculture in Eastern Siberia, where there is a shortage of manpower and the transportation of fuel to remote agricultural regions is difficult. However, the effectiveness of these measures depends considerably on local conditions and must be confirmed by special calculations in each individual case.

With the consideration for the placement of energy-consuming industries in Siberia and the additional directions in the utilization of electric energy in the industrial, transportation, agricultural, municipal, and household processes that have been discussed above, the optimal level of the electrification of the national economy of Siberia and the Far East constitutes 29-30% against 20% of the country as a whole.

Along with the electrification of the national economy, centralized heating with steam and hot water is an important means of increasing the effectiveness of energy supply to the consumers, creation of the appropriate standard of living for the population, a sharp reduction of the need in manpower resources, and insurance of a normal purity of air in cities of Siberia and the Far East.

The orientation of the national economy toward the development of such heat-consuming industries as chemistry and petrochemistry, pulp and paper industry, and wood pulp chemical industry,as well as severe climatic conditions determine the accelerated growth of heat consumption in Siberia and the increase of its share in the heat balance of the country. The same factors are responsible for the concentration of thermal loads. Eventually, the thermal load of individual cities here will reach 7000-10,000 Gcal/h, and heat consumption of cities with thermal loads of over 1000 Gcal/h will constitute about 80% of the total consumption of heat by cities and city-type settlements. The share of cities and settlements with loads below 500 Gcal/h will constitute only 5% of the total heat consumption.

At the present time, one half of thermal loads of Siberia are covered by TETs, approximately one third of them are covered by rayon and industrial boiler rooms, and the remaining heat consumption is satisfied by decentralized sources: small boiler rooms and heating furnaces. Almost all sources of heat supply work on coal.

The ecological and economic factors make it necessary to change substantially the conditions of heat supply of medium and small producers of heat. It is permissible to use coal for TETs provided that electric filters are used, while central boiler rooms and particularly small units should be using high-quality fuels: gas, purified coal, and partially fuel oil. Considering the great difference in the expenditures on high-quality fuel for boiler rooms and on coal for TETs, the level of the centralization of heat supply in Siberia must be increased in comparison with the European regions by 30-50%. For the same reason, even without consideration for social factors (purity of the air, comfortable living conditions for the population, etc), the sphere of the development of centralized heating supply is expanding substantially in this region: the minimum level of the concentration of thermal loads at which the use of TETs becomes effective is 20-40% lower in Siberia than in the European regions of the country. Accordingly, the share of TETs in the total production of heat here must constitute 45-47% against less than 40% for the country.

Rapid electrification of the national economy in Siberia (with a high percentage of industries consuming large amounts of electric energy which are responsible for the high density of the overall electric load schedule) in combination with the large share of TETs and favorable conditions for the development of hydropower engineering predetermine the high rate of the development and specific structural peculiarities of the Integrated Power System (OES)of Siberia. At the present time, the share of GES in the structure of power-generating capacities of the OES is approaching one half, the share of TETs is approaching one third, and the share of KES [Condensation Electric Power Stations] constitutes less than one fourth of the total capacity of the system. Analysis of the balance of electric energy production in the OES of Siberia indicates a strained situation, particularly because of excessively high loads of thermal electric power stations while a considerable part of GES capacities is not being utilized. Therefore, along with further construction of GES and further development of TETs, much attention must be given to the construction of KES during the next period.

Two main areas are forming in Siberia for mass (possibly flow-line) construction of very large KES. The first area is connected with the development of the Kansk-Achinsk coal field; its development was started with the construction of the first Berezovskaya GRES. Eventually, the total capacity of electric power stations in this area will reach tens of millions of kilowatts. The energy of these electric power stations is intended for the needs of consumers in Siberia and for transmission (including direct current) to the European regions, Kazakhstan, and Central Asia.

The second construction area of condensation electric power stations is being created in the middle part of the Ob' River (Surgut GRES) and is oriented toward the use of casing-head gas, and later for low-pressure natural gas. At the present time, these KES are intended, and will be intended in the future, chiefly for electric power supply to Tyumenskaya Oblast and the Urals.

Condensation electric power stations will also be developing in other regions of Siberia and in the Transbaikal area primarily for satisfying the needs of local consumers in electric energy.

The hydroengineering construction program for Siberia, along with the completion of the Sayano-Shushenskaya GES and the construction of Boguchanskaya GES, includes the construction of the main GES of the Yenisey system (Sredne-Yeniseyskaya GES, Osinovskaya GES, and Nizhne-Tungusskaya GES) before the end of this century. It is necessary to implement complex optimization of the main parameters of these GES and the delivery schemes of their power. There are reasons to believe that it is preferable to transmit the power of the Yenisey GES to the Urals and further to the European regions. In this case, the installed GES capacities must be selected with consideration of the fact that they will operate chiefly in a basic mode during the first stages, and their economic indexes must be competitive with the AES in the Ural and Volga regions.

The internal and intersystem electric connections of the OES of Siberia will be strengthened substantially during the next period. Provisions will be made for its parallel operation with the OES of the Urals, Kazakhstan, and Central Asia with the use of high-voltage alternating current electric power transmission lines.

Along with this, after the construction of a direct current 1500 kV VL [overhead line] Ekibastuz -- Center, possibilities of constructing a direct-current VL of higher voltages are being examined for supplying the power of the electric power plants of the Kansk-Achinsk complex and, possibly, the power of the hydroelectric power plants of the Yenisey system to power associations of the European part of the country.

The total carrying capacity of the intersystem connections will reach tens of millions of kilowatts. Electrical connections with the Transbaykal area and the Mongolian People's Republic will be strengthened. It is expected that the OES of Siberia will be linked with the OES of the Far East along the BAM route.

Along with the development of the electric power and heat supply, an important role in increasing the effectiveness and pace of economic growth of Siberia is played by the improvement of the conditions of fuel supply to the consumers. Multivariant calculations in the optimization of the fuel and energy balance of Siberia within the framework of the fuel and energy complex of the country have indicated the possibility of solving this problem without any damage to the fuel supply of the European regions of the country and with consideration for export needs.

Coal remains to be the predominant kind of fuel and will continue to be in the future. However, its overall percentage in the balance will decrease from two thirds to one half as a result of increasing percentage of natural gas. It is expected that the distribution of coal by consumer categories will improve: the percentage of its comsumption by electric power stations remains unchanged, and its replacement with gas will occur chiefly among small consumers, in technological processes, and, partly, in boiler rooms. However, the percentage of natural gas will increase somewhat even at electric power stations (at Surgut GRES and, partly, at the electric power stations of the Noril'sk industrial complex).

Siberian consumers can benefit greatly from technological reprocessing of Kansk-Achinsk coal and the production of smokeless solid fuel (semicoke) and liquid fuel (resin) for households and small boiler rooms. In a more distant future, it will be necessary also to process coal for producing liquid fuel.

The main means of solving the problem of improving the fuel supply services to the consumers of Siberia is to accelerate the installation of gas supply facilities in economically developed areas. Of course, under any conditions, the density of gas consumption will be much lower than in the European regions of the country, not only because of the lower density of the population, but also because of the much lower effectiveness of the use of gas instead of coal. And nevertheless, gas supply for most regions of Central Siberia will be economically justified.

In Western Siberia, it will be effective to have gas supply in almost all oblast cities, large industrial centers, using gas for technological and household needs, for small and medium boiler rooms, and, selectively (primarily with consideration for ecological factors), for large boiler rooms and some TETs. The following gas must be used for these purposes: (after reprocessing at GPZ [gas processing plants]) casing-head gas of the fields of the middle Ob' River area, gas of small fields of Tomskaya and Novosibirskaya oblasts and later, if necessary, some of the Tyumen' gas sent to the European regions through Surgut and Tyumen'. The same sources must provide gas for large consumers in the western regions of Krasnoyarskiy Kray.

It is expedient to orient the gas supply for main industrial centers of Irkutskaya Oblast toward the successfully prospected resources of natural gas deposits in the Lena River area. The sphere of its use among the consumers here is the same as in the regions of Western Siberia, but technolocical use of gas is much greater.

In conclusion, it is necessary to stress that all elements of the fuel and energy complex are characterized by a high degree of inertness. Realization of large structural and territorial shifts requires considerable periods of time. This applies equally to the fuel and energy bases of Siberia whose role in the solution of long-range power problems of the country increases sharply. Therefore, the implementation of extensive programs for the creation of large fuel and energy bases in Siberia requires unabated attention and optimal coordination of the unionwide and regional problems in accordance with Comrade L. I. Brezhnev's instructions given during his tour of the regions of Siberia and the Far East.

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ELECTRIC POWER AND POWER EQUIPMENT

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ECONOMIC ASPECTS OF CENTRAL HEATING GROWTH SHOWN

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[Article by A.S. Gorshkov and Ye.Ya. Sokolov, doctors of technical sciences, VTI-MEI: "National Economic Effectiveness of Central Heating in the USSR"]

[Text] The economic development of the Soviet Union is based only on its own fuel and power resources. Energy independence is an important advantage of our economic system and a very important prerequisite for its stable growth. In order to realize this advantage in full measure it is necessary to strive for rational and economical utilization of resources [1].

It is required strictly to observe and intensify the regime of a saving of fuel and power resources for the purpose of insuring a balance of them. From the national economic standpoint it is necessary to conduct measures directed at a saving of fuel and power resources at the present time and in the remote future. Under the conditions of a strained fuel and power balance, rational utilization of fuel, heat and electric power will lead both to an increase in the economical nature and in the reliability of the energy supply.

Observance of a regime of saving fuel and power resources is not only a scientific technical and production-economic problem, but also an important social task [1].

In the country's fuel and power balance at the present time about 23 percent of the utilized resources falls to electric power and 37 percent to heat. These resources are being concentrated more and more in power engineering systems, and therefore placed on them is the greatest responsibility for insuring their rational and economic utilization. The specific expenditure of fuel for the production of energy has become not only a sector indicator, but also a major national-economic indicator, which is pointed out in the directives of the party and the government and appears in the state plans [1].

Already conducted successfully and being conducted in the power systems is extensive work for insuring the assigned reduction in the specific expenditure of fuel by the end of the Tenth Five-Year plan to 325-328 grams per kilowatt-hour. The average reduction in the specific expenditure will be attained with ever greater difficulties and outlays of labor, of physical and monetary means. In turn, in absolute terms 1 gram of specific expenditure yields at the present time about 1 million tons of standard fuel per year and as there is a further increase in the production of electric power this value will grow, contributing to an expanded energy supply and to a rise in the effectiveness of public production [2].

One of the main directions of further rational and economic utilization of fuel and power resources, of a radical improvement in the country's fuel and power balance is centralized complex production of electric energy and heat--a central heating system. This has been proven by the half-century of know-how of our country, which steadily occupies first place in the world with respect to the level of its development.

In the planned socialist economy of the USSR the central heating system is being developed at high rates, which is evidenced by the data for 1950-1975 [3].

Production of fuel and power resources, million tons of standard fuel	345-1730
Production of heat, million gigajoules	1680-10,500
Including TETs [heat and electric power plants], million gigajoules	290-3800
Production of electric power of TETs, billion kilowatt-hours	27-320
Including for the heating supply cycle, billion kilowatt-hours	9-200

One of the important indicators of the effectiveness of heating supply is the saving of fuel in comparison with the separate scheme of centralized energy supply for KES [condensation electric power plants] and heating supply from large regional boiler plants. This effect by the end of the Ninth Five-Year Plan reached approximately 35-40 million tons of standard fuel per year. Such a saving is comparable with that provided by all the hydroelectric power plants of the Union (about 40-45 million tons of standard fuel per year). Necessary however is a more objective evaluation of the effectiveness of central heating in comparison with the actual scheme of a replaceable separate energy supply [3]. Under actual conditions the introduction of a TETs, as a rule, leads to ceasing the construction of new boilers and the operation of existing small low-economy boilers. In such a case the attained effect of central heating is evaluated as a saving of fuel of approximately 100 million tons of standard fuel per year [3]. Thus, according to different estimations, the TETs already provide annually a saving of fuel in the limits of 30-100 million tons of standard fuel. This effect of a saving of fuel can be evaluated in various ways.

If the resources of power fuel were not limited, the indicated saving of it would lead only to reduction of the corresponding outlays for extraction and delivery, which in today's prices come on the average to 15.5 rubles per ton of standard fuel or on the whole 465-1550 million rubles per year. If we figure according to the so-called closed expenditures, which even according to lowered estimates come to 30-35 rubles per ton of standard fuel, then the fuel effect of central heating supply can be estimated at 900-3500 million rubles per year.

In fact the resources of highly valuable energy fuels are limited. Under these conditions an additional release of energy is insured owing to the economized fuel. Thus, produced all together in 1975 was 1038 billion kilowatt-hours, including 90-300 billion kilowatt-hours on fuel economized thanks to central heating, which comprises 9-30 percent in the total release, that is, a very substantial share. This means that the effect of central heating supply is manifested also in an additional release of electric power on the economized fuel. This ultimately is reflected in the volume of industrial production and the national income. The national economic effect of central heating supply from the additional release of energy is proving to be significantly greater than the above-indicated cost of the economized fuel.

Heating supply source	Release of heat: million gigajoules/year	%	Expenditure of fuel: million tons st. fuel/year	%
Heat and electric power plants	4000	33	124*	23.5
Large boiler rooms (more than 60 megajoules/s)	1300	11	55	10.5
Small industrial and apartment boiler rooms (less than 60 megajoules/s)	3100	25	146	28
Decentralized sources	3400	28	200	38
Secondary energy resources	300	3	0	0
Total	12100	100	525	100

*Taking into account the saving of fuel from combined output.

It is necessary to consider also that thanks to central heating there is a significant reduction in the discharge of products from burning fuel and heat, which corresponds to meeting the demands about protection of the environment and creates the possibility for an increase in power capacities in regions where this is limited by sanitary norms.

There is a reduction in the demands for cooling water for condensation of spent steam in the heating supply installations, which creates the possibility of increasing the energy capacities in regions with limited water resources.

The work of the TETs increases the reliability of the electric power engineering system thanks to the output of electrical capacity at the site of its consumption. In forcing out the small boiler rooms, the TETs release vast manpower resources that have been occupied in their erection and servicing.

It is obvious that the effectiveness of central heating supply is reflected not only in the indicators of the power engineering sector, but also of the whole national economy. The effectiveness must be revealed and evaluated with adequate completeness in order to uphold the right to further development in the case of increased demands on guaranteeing the effectiveness of capital investments. The difference in the economical nature of heating supply and condensation equipment with increased parameters of steam is being reduced. The resources of less expensive coal of the eastern deposits are appearing. Atomic heat and electric power plants are promising. In realistically evaluating the effect of different conditions, one can conclude that integrated production of electric energy and heat using fossil fuel should receive further development.

In the presence of considerable advances in the development of technology and the scales of heating supply, and also the improvement of indicators of operation, its effectiveness still has been far from fully manifested, since many well-known scientific-technical and practical measures have not been carried out [2-4].

Presented in the table are data characterizing the distribution of the release of heat and the expenditures of fuel according to sources of heat supply during 1977.

As is evident from the data cited, the heat and electric power plants satisfy only one-third of the heating load of the country, using for this purpose about one-fourth of the total expenditure of fuel. Satisfied by small boiler rooms and decentralized sources is still 53 percent of the country's heat load with a consumption of 66 percent of the total expenditure of fuel.

The available reserve of a saving of fuel from forcing out decentralized heating supply and small apartment boiler rooms by centralized heating supply from TETs and large boiler rooms can be estimated according to the level of heat consumption in 1977 in the amount of 125 million tons of standard fuel. This comprises about one-third of the total annual expenditure of fuel for the output of electric power in the country.

In order to realize the indicated vast reserve of a saving of fuel, the rates of development of central heating should be increased, but they are being reduced. Cause for alarm is the fact that during 1977 the release of heat from TETs of the Ministry of Power was increased by a total of 25 million gigajoules, that is, by less than 1 percent, instead of the increase of not less than 125 million gigajoules per year during the previous period.

This directly affected the lowering of the average specific expenditure of fuel at the TETs, which in 1977 came to only 3.6 grams per kilowatt-hour instead of an annual reduction by 8-9 grams per kilowatt-hour in preceding years. It should be kept in mind that in certain cases the planned and the realized limitation of the release of spent heat to consumers from the TETs leads to a reduction in the absolute expenditure of fuel just at the TETs themselves, but in this case there is an overexpenditure of fuel in the country since the heat load that is not released from the TETs is made up, as a rule, from boilers with a low level of economy.

On the average an under-release of heat from TETs in the amount of 1 million gigajoules leads to an overexpenditure in the country of 24,000 tons of standard fuel, and of this amount 65 percent is as a result of recution of the combined output of electric energy and 35 percent is due to decentralization of the heating supply. As we see, a large part of the damage occurs from reduction in the output of electric power in the heating supply cycle at the TETs.

Often cited as reasons for limitation of centralized heating supply from heat and electric power plants are references to the extremely high cost of transit heat-carrying pipes, which are an integral element of many modern large TETs. They are placed according to ecological, health and lay-out conditions on the outskirts or even beyond the boundaries of modern cities, while regional boiler rooms can be located closer to the heat consumers.

It should be kept in mind that even with removal of the TETs to a distance of 15-20 kilometers from the city limits the specific initial expenditures for transit heat-carrying pipes from modern high-capacity TETs with an estimated heating load on the order of 1700-2300 megajoules/s and more come to approximately 9,000 rubles per 1 megajoule/s. The specific annual saving of fuel in the case of combined output of electric power at modern TETs comes to about 175 tons of standard fuel per 1 megajoule/s of the calculated heating load. Therefore the initial outlays for transit heat-carrying pipes even with a significant distance of the TETs from the city come to about 50 rubles per ton of standard fuel saved per year, which is 3-4 times lower than the specific initial outlays for creation of a fuel base and the corresponding transport communications for 1 ton of standard fuel per year.

In connection with the overloading of the utilities transporting fuel from Siberia to the European part of the USSR, certain specialists are proposing to limit the further development of the central heating system using fossil fuel in this part of the country by means of satisfying the growth in the heating load from boiler facilities and covering the increase in the electrical load from atomic condensation plants (AKES; atomic condensation electric power plants). It is necessary to point out the doubtful effectiveness of this proposal in general and from the positions of limitation of the delivery of fossil fuel in particular.

At modern TETs for every 100 megawatts of installed electrical capacity released per year is 4.6 million gigajoules of heat with a specific expenditure of standard fuel of approximately 41 kilograms per gigajoule and 500 million kilowatt-hours of electric power with a specific expenditure of fuel of approximately 220 grams per kilowatt-hour. The annual expenditure of fuel for the indicated release of heat and electric power comes to 300,000 tons of standard fuel, and out of this 190,000 tons of standard fuel (64 percent) is expended for the output of heat and only 110,000 tons of standard fuel (36 percent) is expended for the output of electric power. The basic share of the fuel is expended for the output of heat.

As practice shows, lowering the rates of development of central heating supply, as a rule, leads to decentralization of heating supply and the connected substantial increase in the specific expenditure of standard fuel for the release of heat up to 53-58 kilograms per gigajoule instead of 40-42 kilograms per gigajoule in the case of central heating supply. Therefore the expenditure of fossil fuel for heating supply increases by 30-35 percent. In the case considered the expenditure of fuel just for heating supply, that is for the release of 4.6 million gigajoules of heat, comes to 250,000 tons of standard fuel. At the same time there is a substantial increase in the expenditure of fuel for the output of electric power according to the condensation cycle, which comes to 170,000 tons of standard fuel. The total expenditure of fuel in the case of separate energy supply comes to 420,000 tons of standard fuel per year, that is it exceeds the annual expenditure of fuel in the case of central heating supply by 120,000 tons of standard fuel, or by 40 percent. In addition the delivery of fossil fuel is reduced only by 50,000 tons of standard fuel per year, that is by 17 percent of the total expenditure of fuel at the heat and electric power plants, but the overexpenditure of fuel in the country comes to 120,000 tons of standard fuel per year, that is 40 percent of the total expenditure of fuel for the output of heat and electric power at the TETs.

According to the expert evaluation of the authors, the heat consumption in the European USSR in 1980 will reach 10,500 million gigajoules per year, including 3500 million gigajoules per year, or 33 percent, from the TETs. From these TETs 300 billion kilowatt-hours of electric power will be issued. In this case the annual expenditure of fuel at the heat and electric power plants comes to 210 million tons of standard fuel, including 145 million tons of standard fuel for the output of heat and 65 million tons of standard fuel for the output of electric power.

In the absence of central heating supply the expenditure of fuel for heat would come to 200 million tons of standard fuel and for electric power 100 million tons of standard fuel, and in total 300 million tons of standard fuel, that is 90 million tons of standard fuel more than with central heating supply.

A reduction in the rates of development of central heating supply in the European USSR will lead to a substantial overexpenditure of fuel without any marked effect at all in reducing the delivery of fossil fuel in the European part of the USSR.

The positions stated preserve their force also in the cautious hypothesis that instead of the TETs, heating supply will be realized by 50 percent from large boiler facilities and by 50 percent from small boiler facilities.

Also warranted is the development of heating supply from atomic TETs. Of course, it follows to depend in the development of heating supply on the new sources of energy--atomic, and thermocuclear, but it is necessary realistically to evaluate the possibility of their utilization in time. Until practical mastery and broad development of atomic TETs it is necessary as before to develop heating supply using fossil fuel, improving the techniques and organization of construction and operation of the heating supply systems, including the consumer installations.

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ELECTRIC POWER AND POWER EQUIPMENT

ELECTRIC MACHINES HAVE MAJOR ROLE IN UZBEK IRRIGATION

Moscow PROMYSHLENNAYA ENERGETIKA in Russian No 10, Oct 78 pp 2-3

[Article by engineer L. A. Yevdokimov, Uzenergosbyt: "Electromechanical Irrigation of Land in the Uzbek SSR"]

[Text] During the years of Soviet rule in the republics of Central Asia large areas of barren virgin steppe land have been irrigated, as have unused lands on the edges of old irrigation systems. Lands elevated and remote from water supply sources are being irrigated with water pumped up by electromechanical means. To this end arterial canals are built with pumping stations at stepped levels so as to provide not only for getting water up to the tracts to be irrigated, but also for maintaining irrigation during periods when flow and water levels are low. Diversion of water into the arterial canals is accomplished by means of large engineering facilities which function reliably whatever the water levels in the rivers.

Particularly extensive operations in irrigation of virgin land by electromechanical water lift are going on in the Uzbek SSR where about 30 percent of all irrigated land in the country is concentrated. Work on irrigation of land in the Karshinskaya, Dzhizakskaya and Surkhan-Sherabadskaya steppes is in process, and irrigation of the Golodnaya steppe and lands in Bukharskaya Oblast is being finished. This involves the use of a complex approach to opening up the virgin steppes, which covers not only bringing in water and building collection and drainage nets but also the construction of well-organized sovkhoz farmsteads, putting in roads, power lines and water lines, attracting people etc. Such an approach is making it possible to establish in Central Asia an irrigation system which has great national economic significance and is actively affecting the development and disposition of productive forces.

Extensive electromechanical irrigation to put large tracts of land to use began developing in about 1962 with the construction of the Amu-Karakul'skiy machine-aided canal with a flow of 48 m^3/s and two electric pump stations providing for a water lift of 15 meters. A project was developed on the basis of this canal to feed water from the Amudar'ya into a Bukharskaya Oblast central oasis, whereby the head reservoir of the Amu-Bukharskiy machine-boosted canal was integrated with the head equipment of the Amu-Karakul-skiy canal, which was expanded to provide for a flow capacity of 141 m^3/s.

In Surkhandarinskaya Oblast the irrigation of the Surkhan-Sherbadskaya tract is being accomplished by means of the Zang arterial canal and the machine-boosted Shirabadskiy and Amu-Zang canals. Irrigation of the Karshinskaya steppe relies on the Karshinskaya arterial canal which has six electric pump stations providing a 140-meter lift and flow capacity of 200 m^3/s.

When we are dealing with arterial canals with electric pumping stations lined up on them we have the problem of coordinating the operation of the stations since, if one stops while the rest are working, the canal might overflow and the stopped station might get flooded. Full or partial stoppage of the pumping equipment at the rest of the stations disrupts the hydraulic regimen of arterial and branch canals. In the growing season this can upset cotton plant watering schedules. In connection with this it is necessary to ensure a high degree of reliability with respect to the power supply to pumping stations on arterial canals.

Electromechanical irrigation will, in the future, be accomplished via the construction of large stations with high-capacity pumping equipment. The installed capacity of pumping stations is, as a rule, selected by starting from the maximum summer productivity during the growing season, taking into account the capacity of reserve equipment. The facilities of the large arterial canals with large electric pumping stations for lifting water makes it possible in many cases to resolve the technically complex problem of transferring water from major water arteries into the basins of rivers carrying little water.

Besides the major pumping stations of the arterial canals there are stations having local significance in the republic. These include floating and fixed stations which provide for replenishing water in the irrigation canals. There is, moreover, extensive employment of electromechanical listing of ground water for irrigation using vertical wells. Central vertical pumps rated at 22 - 45 kW are used for the purpose, lifting water 35 meters with an output of 44 - 105 l/s.

The main sources of water and hydroelectric power in Central Asia are the Amudarya and Syrdarya and their tributaries. Due to the fact that the possibility of building large hydroelectric stations and the reservoirs associated with them are extremely limited where the rivers traverse flatlands, they are being designed and built on the rivers' upper reaches--in the mountainous areas. The intensive utilization of the waters for irrigation is becoming a basic factor in the modification of the flows. Regulation of the flow of the rivers is therefore subordinate to irrigation conditions, and the power stations' water storage basins are compelled to function mostly according to the irrigation schedule. The result is that the hydroelectric stations don't reach their installed capacity and the shortfall has to be made up by thermal stations.

The growth of summer loads on the Central Asian power system has become a regular thing in recent years in connection with the deve-opment of irrigation based on the use of electromechanical facilities. In the Uzbek part of the power system the maximum load during the growing season is more than 90 percent of the winter maximum. The active capacity contributing to the power system's maximum amounts to 310 MW for the Karshinskiy canal pumping stations and 220 MW for the Amu-Bukharskiy canal pumping stations. According to the data of 1 January 1978, the installed capacity of pumping station equipment for the Amu-Bukharskiy canal is 335 MW, Karshinskiy primary 450, "Sherabad" stations 45, and all others 554 MW.

The expanding electromechanical irrigation is now a significant user of electric power (some 13 percent of the republic's overall consumption). Over the last decade the consumption of electric power by pumping stations has shown an 18-fold increase, most of it attributable to the large stations. Thus, the pumping stations of the Amu-Bukharskiy canal use 1135 million kWh of electric power, Karshinsky primary 1381 million, "Sherabad" 259 million, and all others 1240 million.

Power is supplied to the large pumping stations via overhead 110-220-kV network lines. The other stations are fed by lines carrying 6 - 35 kV. The substations for the electric pumping facilities serve not just the pumping facilities but the areas around them as well.

Since the large pumping stations have such a large intake, a change in their operating schedule causes a change in and upsets the stability of the power system switching center which is routing power to the pumping stations. The problems of reliability in supplying power for the large pumping stations are, in effect, system problems.

Whatever the system's operating conditions, it is necessary to ensure an economical supply of electric power of satisfactory quality to the consumers at minimum possible expenditures for production, transmission and distribution. The need for high reliability in supplying major pumping facilities with electric power stems not just from the desire to avoid disrupting the hydraulic regimen of the irrigation system, but from the fact that the electric motors with which the pump assemblies are equipped require non-routine major overhaul after 20 start-stop cycles.

The reliability of the electric power supply system rests upon system facilities and control equipment being there, reserves adequate to cope with negative effects, reliable equipment and capable personnel, i. e., an all-round satisfactory level of operational organization.

The normal functioning of an electric power supply system depends essentially on the operational reliability of the equipment, which depends, in turn, on the equipment design, quality of production and installation, how it is operated and maintained, and how it is repaired. We have to note that the quantity of equipment running the pumping stations and the canal as a whole cannot be forecast on a regular basis because it depends on geophysical processes.

The question of possibly starting directly or self-starting of pump facility electric motors has not yet been answered. The effects of individual and group self-starting of these electric motors on the stability and reliability of operation of the power supply system of the large pumping stations has not been looked into to the degree necessary. The optimum operating conditions for the electric motors of the pumping equipment and the stations as a whole have not been determined.

The problem of providing a reliable power supply for the pumping stations and ensuring stable operation of the power system load centers is a component part of the overall task of optimizing their development since the reliability rating of the system has to be inside economical limits. In the initial stage, one can talk about the correcting effect of the factor of reliability upon optimum solutions. Subsequently, it is necessary to find the optimum solutions wherein the factor of reliability (taking into account the operating conditions of large electric pumping stations for the power system) is an integral component in the calculations.

In the years just ahead for the Uzbek SSR, the arid lands will have to be developed through electromechanical irrigation. To this end, for the purpose of irrigating the Dzhizakskaya steppe there is being built the first phase of an arterial canal with four electric pumping stations which will raise water more than 200 meters. The power supply of the canal's pumping stations will be 220 kV from the Syrdarya center of the power system. At the present time, construction is winding up on a pumping station with a two-transformer substation of 220/110/10 kV (two autotransformers at 200 MVA each). The projected consumption of the canal's pumping stations is 375 MW.

For the further irrigation of the Karshinskaya steppe lands, it is proposed to build a second phase of the Karshinskaya arterial canal. The proposed capacity for the pumping stations of the canal's second phase is 450 MW.

Since the water resources of Central Asia are limited, the further development of agriculture by irrigation can be handled by feeding water into the Aral Sea basin from outside. Preliminary investigation shows that the problem of shifting water from the Siberian water arteries into the basins of the rivers of Central Asia will be successfully solved by means of arterial canals with high-output electric pumping stations lifting water to the water divides.

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ELECTRIC POWER AND POWER EQUIPMENT

ELECTRIC POWER ENGINEERING USSR STATE PRIZE AWARDS FOR 1978

Moscow ELEKTRICHESTVO in Russian No 2, Feb 79 pp 1-3

[Text] By resolution of the Central Committee of the CPSU and the USSR Council of Ministers published on 7 November 1978, a group of workers in electric power engineering and the electrotechnical industry were awarded the 1978 USSR State Prize for "Creation and Introduction of Powerful High-Voltage Automatic Power Transformers into Power Engineering." The honorary rank of USSR State Prize Laureate was conferred on K. M. Antipov (Glavtekhupravleniye of the USSR Ministry of Power Engineering), V. A. Ivanov, candidate of technical sciences V. M. Sukhanov, E. G. Troyan and Yu. I. Glazunov (Zaporozhtransformator Planning Section), candidate of technical sciences A. G. Kray--, candidate of technical sciences S. D. Lizunov and A. M. Gorbunov (MosPO Elektrozavod Plant imeni V. V. Kuybyshev), A. I. Mayorets (USSR Ministry of Electrotechnical Industry), N. P. Fufurin (All-Union Scientific Research Institute of Electric Power Engineering), candidate of technical sciences V. M. Chornogotskiy (All-Union Scientific Research, Planning and Design and Technological Institute of Transformer Construction) and S. I. Rabinovich (All-Union Electrotechnical Institute imeni V. I. Lenin).

The 150-500 kv automatic power transformers and higher rated ones are a new form of transformer equipment, and the work on the creation of them is a new area in the development of transformer construction. The significance of this work goes beyond the framework of the basic improvement of one of the most important types of electrical equipment. The introduction of the high and superhigh voltage automatic power transformers has had decisive significance for the development of all Soviet electric power engineering during the postwar period, and it has opened up new paths of its further development.

The application of the automatic transformer principle in power transformer construction has made it possible not only to introduce basic improvements in the technical-economic indexes of the large general-purpose transformers (a reduction of the consumption of electrotechnical steel by 30 percent and winding copper by 10 percent, a decrease in the electric power losses and total weight of the automatic transformers by 35 percent), but also, and what is no less important, to increase the power of the automatic transformers transportable by railroad in a single unit by two or more times by comparison with transformers with the same voltages.

The creation of the high powered automatic power transformers to operate at high and superhigh voltages has required an enormous amount of scientific and engineering research--electromagnetic, insulation and thermal--the solution of problems connected with the development of new structural elements.

One of the peculiarities of the automatic transformers is that the magnetic dispersion fluxes occurring in them greatly exceed the dispersion fluxes in the analogous transformers. These fluxes can cause significant additional losses and local heating in the wires of the windings, the core of the magnetic system and different structural elements (the pressing rings, the armature beams, the tank walls, and so on). On the basis of the research that has been performed, effective methods have been developed to reduce the additional losses and heating of the indicated elements. In particular, in order to decrease the additional losses in the windings, split and transposed conductors have been developed and used; a study has been made of the effect of lowering the additional losses in the plates of the edge packets and other elements of the magnetic system, and methods of accomplishing this have been developed; studies have been made of the methods of channeling the dispersion fluxes by using magnetic shields on the walls of the tank and the webs of the armature beams, and the execution of the rings pressing the windings from nonmagnetic materials or electrotechnical steel.

As a result of these and other measures, additional losses in the windings and structural elements have been reduced by tens of percentages.

In the automatic transformers, alongside the higher voltage series winding there is a common winding also of relatively high voltage class (110 kilovolts or more). This determines the specific problems of protection against lower voltages and the peculiarities of the operation of the principal and longitudinal insulation. The studies of the electric field on mathematical models, the electric strength of the elements of the principal and longitudinal insulation and the insulating structural elements as a whole on the diminished and full-scale models have made it possible to increase the admissible intensities of the electric field, to develop and introduce efficient structural designs and decrease the dimensions of the insulation while maintaining or even increasing its electric strength.

The studies of the distribution of the pulse overvoltages along the winding, including the use of a digital computer, have led to the creation of new types of windings with the pulse voltage distribution approaching linear. The peculiarities of the distribution of the pulse overvoltages in the windings of the automatic transformers have also been discovered, and the necessity for special requirements on the protection of the automatic transformers from overvoltages in operation has been demonstrated.

The high unit powers of the automatic transformers causing the release of significant amounts of heat in relatively small volumes have required investigation in the development of new highly effective methods of removal of heat from its sources (the magnetic system and the windings) and transfer of it to the external environment.

The studies of the heat transfer processes from the magnetic circuit and windings to the oil, the processes of moving the oil in the horizontal and vertical cooling channels, the heat transfer from the oil to the walls of the tank and the elements of the cooling system have ensured the development of new types of cooling and improvement of the previously used cooling systems with forced and forced-directional circulation of the oil in the active part of the automatic transformer. This has made it possible to increase the specific thermal loads in the automatic transformers by 1.25 to 1.4 times without a noticeable increase in the expenditures and maintaining the admissible excesses of temperature of the parts inside the automatic transformer according to the effective IEC standards and recommendations.

The voltage regulation systems usedin the transformers are unsuitable for automatic transformers. Accordingly, studies have been made of various systems for direct and indirect voltage regulation (on the high voltage side, the medium voltage side, in the common neutral of the high voltage and medium voltage windings), which has made it possible to develop the most efficient regulation systems considering the peculiarities of the automatic transformers. These studies have also served as the basis for creating new fast-operating RPN resistor units. In addition, broad studies have been made of the insulation of the adjustable windings of the automatic transformers and the switching units. They have made it possible to develop standards which have been used for the basis for creation of the structural designs of the RPN automatic transformers and the RPN devices.

A large volume of scientific research work has been aimed at improving the mechanical strength of windings and structural elements under the effect of short circuit currents, improving the technological processes of manufacturing the automatic transformers, methods of transporting them, installing, operating and maintaining them.

The creation of the series of high-voltage autotransformers in a wide range of powers and voltages has also demanded a large volume of experimental and planning and design work. It is necessary to note here that the structural elements of the most widely used types of autotransformers have been revised many times since their initial development and improved considering the increased demands of the power engineers and also with the use of the results of scientific research work and new technological processes and the application of improved materials and kit products.

As applied to the autotransformers and other types of transformer equipment, structural elements have been developed for magnetic systems ensuring maximum use of the specific properties of the textured cold-rolled electrotechnical steel. Considering the peculiarities of the autotransformers, new types of windings have been developed and introduced--continuous without shielding turns and additional insulation on the coils, intertwined and combined. New structural designs have been developed for the regulating windings, including with increased dynamic strength. In the automatic transformers that are adjustable under load, special compositions have been used with location of the adjustment winding outside the basic windings on the basic cores of the frame and also on the side armatures which ensured an increase in the dynamic strength of the windings and improvement of their characteristics. Significant improvements have also been introduced into other structural elements of the autotransformers--leads, tanks, cooling systems and so on and also the methods of protecting the oil from oxidation and aging.

The mastery of the production of powerful, high-voltage autotransformers has been an additional impetus to the improvement of the existing technological processes, attachments and process equipment and the development of new ones which then have become widespread on all transformers. Automatic lines for longitudinal cutting of the rolled electrotechnical steel and transverse layout of the plates of the magnetic circuits, test units for assembling the frames, a device for pressing them and mechanized application of the glass bands have been developed and assimilated. All-purpose mandrels and special units for axial pressing of the coils while winding them and special vertical winding machines have been built to manufacture the coils. An original unit has been developed and introduced for pressing windings under their own mass during the process of drying them. Significant improvements have been introduced into the processes of thermal vacuum treatment of windings and the active parts of automatic transformers.

The procedure for qualification and acceptance testing of autotransformers has been improved significantly. The methods of measuring the intensity of the partial discharges when testing by industrial frequency voltage have been improved. New devices have been introduced into the process of installing the autotransformers in order to keep the insulation from getting wet.

The advantages of using autotransformers for substations with a rated voltage of 150 kv or higher are determined by the basic properties of the autotransformers, in particular, the decrease in size, cost, losses, ratio of losses in the steel and copper, and the no-load current. Considering the economical nature of the autotransformers, it turns out to be advantageous to install larger units at the substations with prospects for growth of the load over a longer time interval. The consolidation of the powers of the substations for installation of autotransformers will permit the number of substations with high-voltage distribution units to be reduced, providing the users with deep inputs on medium voltage.

At the thermal and hydroelectric power stations (in contrast to foreign practice) the autotransformers are also used as step-up units with connection of generators to their third winding. This makes it possible to obtain significant economy as a result of great flexibility of the electric circuits and the possibility of connecting greater generating capacity to the medium voltage distribution unit with the same load distribution.

The development and introduction of the powerful high-voltage autotransformers into power engineering in the Soviet Union has a number of theoretical differences from their application in foreign practice. The scales of introduction of autotransformers into USSR power engineering have greatly exceeded the foreign scales where the autotransformers have limited application and are basically used only for connecting the networks to the different rated voltages at the junction substations of the power systems.

The USSR has specially developed and introduced step-up autotransformers at many of the hydroelectric and thermal power stations differing from the step-down transformers in that without additional transformation they make it possible to release the generator power and couple two systems with different voltages. In the Soviet Union autotransformers are being developed and introduced with broader range of transformation coefficients than abroad--up to 4.6:1.

With respect to the technical-economic indexes (efficiency, losses and mass per unit power) the Soviet autotransformers are not inferior to the best foreign models, and in a number of cases they are superior to them. The damageability indexes of the Soviet autotransformers do not exceed the corresponding indexes of the analogous foreign units, and for the autotransformers manufactured after 1970, they correspond to the minimum values recorded in the foreign power systems in the best years.

The high technical level of Soviet autotransformers reached in recent years ensured their high competitiveness on the international market--they are exported to more than 30 countries.

Since the beginning of their introduction in the USSR, more than 2,000 150-500 kv autotransformers have been manufactured with a total power of several hundreds of millions of kilovolt-amperes. The provisionally released power exceeds 140 million kilovolt-amperes, the released no-load losses amount to more than 110 thousand kilowatts, the short-circuit losses, more than 350 kilowatts. For specific annual expenditures in power engineering of 91 rubles to compensate for 1 kilowatt of no-load losses and 23 rubles for short-circuit losses, the cost benefit from introducing the autotransformers in power engineering amounts to more than 258 million rubles if we consider only the savings of materials (50,000 tons of electrotechnical steel and 12,000 tons of copper winding) and electric power, the annual saving of which amounts to 1.5 billion kilowatt-hours.

The actual cost benefit in the national economy is appreciably higher if we consider the savings in the power systems as a result of consolidation of equipment, improvement of the operating conditions of the electric power transmission lines, economy of transport expenditures for hauling the transformer equipment. In addition, it is necessary to consider that the creation of a broad range of autotransformers has made it possible successfully to solve the basic problem of providing power engineering to the various branches of the national economy with transformer equipment without increasing the production areas and building new transformer plants.

This indicates the great significance to the national economy of the country and, in particular, power engineering, of the work that has been awarded the 1978 USSR State Prize.

The editors of ELEKTRICHESTVO [Electricity] join with their many readers who heartily congratulate the prize winners and wish them new creative success.

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